----------COMMENTS RECEIVED AS OF 10:00 AM 11 JULY 2006----------

SAP 2.1 Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations and Review of Integrated Scenario Development and Applications
Response to Public Comment Collation
26 June 2006 – 12 August 2006

REVIEWERS:

Name: Mohan Gupta, Ph.D.
Organization: Federal Aviation Administration, Office of Environment & Energy
Mailing Address: AEE-300 Emissions Division, 800 Independence Avenue, S.W.,Washington, DC 20591
Phone: (202) 267-3496
FAX: (202) 267 5594
E:mail: Mohan.L.Gupta@faa.gov
Area of Expertise: Atmospheric Chemistry

Name(s): Chuck Hakkarinen
Organization(s): retired
Mailing Address(es): 2308 Cipriani Blvd, Belmont, CA 94002
Phone(s): 650-593-9112 (home) 650-703-6404 (cell)
Fax(es): 650-631-3922
E-mail(s): chakkarinen@comcast.net
Area of Expertise: general climate science

Name: Steven K. Rose, Ph.D.
Organization: Office of Atmospheric Programs, U.S. Environmental Protection Agency
Mailing Address:1200 Pennsylvania Avenue N.W. (MC 6207J) Washington, DC 20460
Phone: 202-343-9553 /
Fax: 202-343-2337
E:mail: rose.steven@epa.gov
Area of Expertise: Economics and integrated assessment modeling

Name: Sarah Wade
Organization: AJW
Mailing Address: 1730 Rhode Island Ave NW, #700, Washington, DC 20036
Phone: 202-296-8086 x2
Fax: 202-289-3588
E-mail: swade@ajwgroup.com
Area of Expertise: Interested Non-Specialist

----------COMMENTS RECEIVED AS OF 10:00 AM 11 JULY 2006----------

GENERAL COMMENTS;

What is the basis of relationship between projected emission scenario and corresponding concentrations of long-lived trace species over the next, say, 100 years given potential changes in atmospheric circulation, chemical interactions and, hence, the lifetime? How this correction is applied while creating concentration fields from emissions? **- Mohan Gupta, FAA**

The report is very nice in that it provides the reader with numerous and insightful points of comparison across models including informative modeling details. However, given that the report is a model comparison and more than just another set of stabilization modeling results from a single model, and is likely to have high visibility with the scenarios potentially being regarded as pseudo-USG scenarios, the report has somewhat of an obligation to provide focused discussions and summaries of (i) key factors behind results differences across models, and (ii) how the scenarios fit into the recent stabilization scenarios literature. Since the exercise did not attempt to "span the range," assign likelihoods, perform sensitivity analysis, nor coordinate on the investigation of specific futures or future assumptions, the report should provide sub-sections dedicated to discussing the key factors behind differences and that help readers put the results into proper context. The report should also be sure to include points from these sections in the Executive Summary and Chapter 5**. [Steve Rose, USEPA]**

A formal single discussion of key factors behind significant results differences is needed, in particular in the context of the IGSM results, which are very different from those from the other models. IGSM suggests, among other things, that substantially more emissions mitigation is required for stabilization, which implies substantially higher stabilization costs than the other models—e.g., over 10% of global world product in 2100 alone for Level 1 vs. less than 2% from the other models. This is an enormous difference that merits a dedicated subsection in Chapter 4, Chapter 5, and the Executive Summary that discusses key drivers of the results and sensitivities. Unfortunately, sensitivity analysis was not part of the 2.1A exercise; however, each of these models has run and published alternative scenarios, in particular alternative reference scenarios. The authors should be able to draw on that experience to discuss the implications of alternative assumptions (e.g., less constrained nuclear penetration, increased ocean uptake, increased penetration of liquid gas fuels, constant marginal costs of coal extraction). The authors might consider providing simple characterizations of the sign and relative magnitude of changes associated with changes in assumptions. **[Steve Rose, USEPA]**

It would be very helpful to add a units of measure appendix or table somewhere for readers (especially policy-makers) not as familiar with the topic and looking across the literature. **[Steve Rose, USEPA]**

While I recognize that space is limited and the scope may be binding, more discussion and figures/tables for non-US regions and results is appropriate. For instance, very different relative emissions pathways are depicted for Annex 1 and non-Annex 1 across models. More discussion (and quantitative illustration) of drivers (e.g., gdp, population, energy, land use, technology options, productivity changes) and the implications for mitigation would be very helpful. At the moment, the reader can review regional reference GDP and population, but is left wonting with

regard to an understanding of how differently (in absolute and relative terms) the models portray other regions of the world. **[Steve Rose, USEPA]**

Thank you for developing these scenarios for public consumption. The combination of three scenarios mutually reinforces the "big picture" concepts related to the scale and magnitude of change that will be needed to address climate change along with the potential role of emerging technologies. At the same time, the differences between the model outputs highlight important limitations that should be considered in using the results to inform policy. The output regarding potential pathways for changes in the energy system could be extremely useful in communicating the need for and potential role of a variety existing and new technologies, such as CCS.

My general comment is that the information in the report is not easily accessible to the decision-makers and others in the public who are not expert modelers but who are an important target of the report. In particular, the Executive Summary does not adequately summarize the findings or the caveats for using the findings that are contained in the report. And, the focus on radiative forcing needs to be presented in terms that are easier to compare to more commonly presented concepts of actual emissions and CO2e or CO2 concentrations. In addition, a close read of the report raises several additional questions of clarification.

I would also point out that the requested format for comments is cumbersome and perhaps will discourage comment. It would have been useful to obtain a briefing on the findings during the comment period so that easily answered questions could be resolved during the comment process. I have organized my comments by general theme and include specific page and line references at the end of each section. **Sarah Wade, AJW**

SPECIFIC COMMENTS:

Part A , Chapter _4_, Page _4-28_, Line _Table 4.1_: Stablization of greenhouse gas concentrations at each of the levels listed (750 ppm, 650 ppm, 550 ppm, 450 ppm) will required VERY SUBSTANTIAL reductions of annual emissions from the current levels of approximately 7 gigatonsn per year. For example, analyses with the MAGIC model of Wigley, et al estimate that stabilizing atmospheric concentrations at 550 ppm will require a reduction of emissions to 1 gigaton per year, which is the level of global emissions that existing in 1927. Put another way, reducing emissions to 1 gigaton per year could be achieved by reducing to ZERO the emissions from the 13 largest emitting countries in the world, and holding ALL OTHER COUNTRIES emissions constant at current levels (i.e., zero growth). Stabilizing atmospheric concentrations at 450 ppm would require even greater emission reductions, perhaps t! o globa l totals of 0.7 gigatons per year, or a 90% reduction globally from current levels. Stabilizing concentrations at 650 ppm or 750 ppm would require emission reductions from the current 7 gigatons per year to perhaps 1.5 or 2 gigatons per year, respectively.

These points should be included in the chapter text, relevant tables, and the Executive Summary to the synthesis report -- these are the type of simple-to-understand numbers that will be most understandable to policy makers and general public alike.
Chuck Hakkarinen, retired

****

Part A, Executive Summary (ES)

Part A, ES, Page ES-9, Line 30

New wording needed – "has the main effect"? **[Steve Rose, USEPA]**

Part A, ES, Page ES-10, Line 6

I'm not sure what the following text means: "…an efficient pattern of increasing stringency over time." **[Steve Rose, USEPA]**

Part A, Chapter 1

Part A, Chapter 1, Page 1-11, Line 29

Citation needs to be revised—here and in the references listing. The correct reference is:

> Weyant, J. and F. de la Chesnaye (eds.). (2006) in press. Multigas Mitigation and Climate Change. Special Issue of the *Energy Journal*
>
> **[Steve Rose, USEPA]**

Part A, Chapter 2

Part A, Chapter 2, Page 2-8, Lines 42-44

As is, it isn't clear these technologies that "are introduced using the same structure" are distinguished within the model. I am fairly certain that I know how, but I think that a more concrete description will benefit the general reader. **[Steve Rose, USEPA]**

Part A, Chapter 2, Page 2-17, Line 1

The table is very useful as is. I wonder if something like it could be used in the summary and chapter 5 with quantitative (or qualitative) information that summarizes the relative quantitative differences across models and pools together results across variables for a few time steps. Food for thought… **[Steve Rose, USEPA]**

Part A, Chapter 3

Part A, Chapter 3, Page 3-1, Lines 23-25

The numbers there would be more meaningful if you add the level values in 2100 vs. the changes from pre-industrial currently reported. **[Steve Rose, USEPA]**

Part A, Chapter 3, Page 3-7, Line 11

It would be extremely useful to include a table in this section that summarizes relative energy costs across sources within a model and across models. Recognizing that a quantitative cost table could be misleading because the values are not always directly comparable, I wonder if it would be possible to identify an energy source that is more-or-less homogeneous across models and then provide some ordinal ranking of the other sources by cost within each model and then a second ordinal ranking of costs across models by energy source type? Ordinal rankings of this kind could be provided by decade or for a few select time periods (e.g., 2020, 2050, 2100). At the moment, it is very hard to think about the cost differences between sources within a model and across models**. [Steve Rose, USEPA]**

Part A, Chapter 3, Page 3-18, Line 10

While there is some discussion of the literature, the comparison is not very informative. It would be more useful to policy-makers and researchers to make a more direct comparison to recent specific scenario results in the literature. For example, in addition to the in press EMF-21 Energy Journal papers, IIASA's MESSAGE and MNP's IMAGE 2.3 integrated assessment models have new stabilization work in press that covers similar targets:

> Riahi, K., Gruebler, A. and Nakicenovic, N., in press: Scenarios of long-term socio-economic and environmental development under climate stabilization. Special Issue of *Technological Forecasting and Social Change*.
>
> van Vuuren, Detlef, Michel den Elzen, Paul Lucas, Bas Eickhout, Bart Strengers, Bas van Ruijven, Steven Wonink, Roy van Houdt, in press-b: Stabilizing greenhouse gas concentrations at low levels: an assessment of reduction strategies and costs, *Climatic Change*.

A comparison on main aspects such as reference global emissions (CO2 and non-CO2), radiative forcing, and energy would provide a better context for the CCSP 2.1A results. For additional possibilities for providing better context, the authors should also review the IPCC WGIII AR4 Chapter 3 Second Order Draft that is currently available for expert review. **[Steve Rose, USEPA]**

Part A, Chapter 3, Page 3-24

Please add "World" totals to Tables 3.1 and 3.2. Also, the order of FSU and E. Europe is not consistent across the three 3.1 tables. **[Steve Rose, USEPA]**

Part A, Chapter 3, Page 3-25

Please convert all the GDP data to the same year (e.g., 2000 US$). **[Steve Rose, USEPA]**

Part A, Chapter 3, Page 3-25

For convenience, please add GDP per capita tables and/or figures. **[Steve Rose, USEPA]**

Part A, Chapter 3, Page 3-27

Please add a figure for global GDP like Fig. 3.2. Obviously, the reader can construct it from the tables, but there is no reason they should have to. **[Steve Rose, USEPA]**

Part A, Chapter 3, Page 3-29

Please add a figure for global primary energy like Fig. 3.5**. [Steve Rose, USEPA]**

Part A, Chapter 3, Page 3-37

Please add figures for US CO2 and non-CO2 GHG emissions. **[Steve Rose, USEPA]**

Part A, Chapter 3, Page 3-41

Why not include the emissions from land use and land-use change in Fig 3.21, or better yet, a second graph that includes the land use emissions? **[Steve Rose, USEPA]**

Part A, Chapter 4

Part A, Chapter 4, General

The stabilization results really need to be put into context with respect to the literature. A direct comparison to recent specific scenario results is necessary to give readers a better sense for how to think about the results. For example, in addition to the in press EMF-21 Energy Journal papers, IIASA's MESSAGE and MNP's IMAGE 2.3 integrated assessment models have new stabilization work in press that covers similar targets:

Riahi, K., Gruebler, A. and Nakicenovic, N., in press: Scenarios of long-term socio-economic and environmental development under climate stabilization. Special Issue of *Technological Forecasting and Social Change*.

van Vuuren, Detlef, Michel den Elzen, Paul Lucas, Bas Eickhout, Bart Strengers, Bas van Ruijven, Steven Wonink, Roy van Houdt, in press-b: Stabilizing greenhouse gas concentrations at low levels: an assessment of reduction strategies and costs, *Climatic Change*.

A comparison on main aspects such as stabilization global emissions (CO2 and non-CO2), radiative forcing, energy, carbon prices, and global world product would provide a meaningful context for the CCSP 2.1A results. For additional possibilities for providing context, the authors should also review the IPCC WGIII AR4 Chapter 3 Second Order Draft that is currently available for expert review. **[Steve Rose, USEPA]**

Part A, Chapter 4, Page 4-10, Line 18

I might have missed it in this section, but it wasn't clear to me how energy efficiency responds to a carbon policy and what proportion of the energy use reductions could be attributed to increased energy efficiency in response to a carbon policy (vs. reduced energy use due to higher consumer energy prices). Energy efficiency is an important emissions reduction strategy and its role should be discussed and illustrated in the figures if possible. At the moment, I feel that the figures implicitly suggest that the exhibited energy reductions are all associated with reduced total use, instead of some improved energy efficiency. **[Steve Rose, USEPA]**

Part A, Chapter 4, Page 4-17, Lines 9-18

This strikes me as odd. My understanding is that IGSM also models land-use competition between ag (crops + pasture), forest, and biomass that, under a carbon policy, includes consideration of forest carbon and non-co2 gases. The text here suggests that only MiniCAM does. Maybe it is simply a matter of re-wording the text to clarify the point being made. Are you trying to say that MiniCAM (via AgLU) models unmanaged land in the economic decision (unlike IGSM). As is, it gives a misleading impression of the land modeling in IGSM. Furthermore, it also gives the misleading impression that MiniCAM is considering the net carbon affects of land-use change decisions (lines 9-12), which as discussed in the next two paragraphs (starting on line 21) is not the case. **[Steve Rose, USEPA]**

Part A, Chapter 4, Page 4-17, Lines 21-43

Sands and Leimbach (2003) should be cited here. Sands and Leimbach illustrate this point very clearly**. [Steve Rose, USEPA]**

Part A, Chapter 4, Page 4-28

Table 4.1 suggests that the concentrations include only CO2 forcing, but not non-CO2 forcing. This is inconsistent with the Executive Summary (page ES-3) which states that these are CO2eq concentrations**. [Steve Rose, USEPA]**

Part A, Chapter 4, Page 4-31

A editing comment from the authors needs to be removed from the text below Table 4.7. **[Steve Rose, USEPA]**

Part A, Chapter 4, Page 4-36

The Figure 4.4 keys appear to have been cut-off**. [Steve Rose, USEPA]**

Part A, Chapter 4, Page 4-38

Given that the report includes the US energy results under stabilization, it would be nice if the report included US GHG emissions results as well similar to Figures 4.6, 4.7, and 4.8. [**Steve Rose, USEPA]**

Part A, Chapter 4, Page 4-44

Would it be possible to illustrate the CCS associated with biomass (BECS) as well in Figures 4.10, 4.11, and 4.14? **[Steve Rose, USEPA]**

Part A, Chapter 4, Page 4-44

Across the energy figures, it would be helpful to be consistent in the order of the level and change results figures. Global primary energy changes are before the levels in Figures 4.9 and 4.10, but levels are before changes in global electricity (Figures 4.11 and 4.12). Consistency will make it easier for readers to find tables and less likely to make a mistake. My preference is for levels before changes. **[Steve Rose, USEPA]**

Part A, Chapter 4, Page 4-54

Please add the following sets of figures:

1. US electricity by fuel levels
2. Global non-electric energy use by fuel – levels and changes
3. US non-electric energy use by fuel – levels and changes

[Steve Rose, USEPA]

****

1. Make the Executive Summary a Stronger Summary

The prospectus states: "The scenarios are intended primarily for decision-makers and analysts who might benefit from enhanced understanding of the potential characteristics and implications of stabilization." It is conventional wisdom that the decision-makers will read the summary and the analysts will dig into the detailed report. This underscores the need for the summary to serve as a stand alone document. From a substantive point of view, the Executive Summary needs to include more quantitative statements, when appropriate, to reflect the findings in the report. Right now, most of the statements in the bullets are broad generalizations that can be of little help to experts or the general public alike. In cases in the Executive Summary where numeric ranges or examples are presented, the points are much more useful and easier to understand.

In addition, the Executive Summary should include at least two sets of graphs in the Reference Case Findings section that summarize all of the scenarios in both radiative forcing and tonnes. It should also contain graphs summarizing the stabilization scenarios in the Stabilization Scenarios Findings section.

Chapters 1 and 5 of the report are very important in framing the scenarios. Chapter 1 reminds the reader that these are but one input to be used in decision making and that the scenarios do not consider the benefits from reducing greenhouse gases. Chapter 5 provides some guidance regarding the limitations on using the scenarios and some insights about how they might be used in the future. These are very important points to reinforce with non-experts and they should be featured more prominently and accurately in the Executive Summary. In several places in the Executive Summary, the frame for considering the costs of changing the energy system is presented in only one-dimension and is not tied to sufficient reminders to the reader that other factors influence the total cost equation. For example, choosing a more stringent radiative forcing limit will increase the magnitude, cost and timing of change in the energy system, but some of these costs might be offset by increases in the benefits of choosing the stringent limit. This may seem like re-stating the obvious or even digressing from the scope of the report, but it is important to remind people that these scenarios are not cost-benefit analyses but rather insights into what it might take to achieve various levels of radiative forcing limitations from the perspective of changes to the energy system. I am not suggesting that this report delve into the policy arena, but I do think it is important that it not leave much room for a reader who is not well-versed in these matters to walk away with the impression that controlling "costs" is primarily a function of choosing a high enough radiative forcing limitation (see ES 8 line 20).

From an editorial point of view, it is difficult to comprehend the information from the Executive Summary because it is presented as a long series of unstructured bullets. I suggest what I think is a more comprehensible structure that would tie findings to the three main questions of modeled emission trajectories, modeled energy system implications and modeled economic implications. To this end, section ES.4 would be restructured as follows:

ES.4. Findings
- ES.4.1 Reference Scenarios
  - ES.4.1.1 Emission Trajectories
  - ES.4.1.2 Energy System Implications

ES.4.1.3 Economic Implications
ES.4.2 Stabilization Scenarios
ES.4.1.1 Emission Trajectories
ES.4.1.2 Energy System Implications
ES.4.1.3 Economic Implications

Within the sections of ES.4., each bullet should be reorganized under the appropriate sub-group and include a paragraph heading that indicates the main point of the bullet. Based on my read, this may result in adding some new bullets and merging others. I would also suggest that where possible broad statements be underscored with quantitative ranges or examples. Some of the specific suggestions are below:

Part A, Chapter ES, Page 1, Line 41: After the first full sentence of the paragraph, add some version of this sentence from Part A Chapter 5, Page 12, Line 4: "Finally, the problem of how to respond to the threat of climate change is ultimately a problem of decision-making under uncertainty that requires an assessment of the risks and how a policy might reduce the odds of extremely bad outcomes. One would like to compare the expected benefits of a policy against the expected cost of achieving that reduction. By focusing only on emission paths that would lead to stabilization, we are able to report the costs of achieving that goal without an assessment of the benefits." The point here is emphasize up front and in a very direct manner that the scenarios present one part of the assessment in forming climate policy. This point should be repeated a few times throughout the Executive Summary. **Sarah Wade, AJW**

Part A, Chapter ES, Page 1, Line 42 and Part A, Chapter 1, Page 1, Line 41: The Executive Summary and Chapter 1 both describe the potential value of the scenarios. They use two different phrasings: The Executive Summary reads "be concerned with the energy system and economics effects of policies leading to stabilization of human influence on the atmosphere," while Chapter 1-1-41 reads: "benefit from enhanced understanding of the potential implications of stabilizing greenhouse gas concentrations at various levels." What is the difference between the focus on stabilizing human influence versus stabilizing GHG concentrations? And, neither statement sufficiently indicates that the scenarios provide insights about the costs but not the benefits of such change. Both questions should be clarified. **Sarah Wade, AJW**

Part A, Chapter ES, Page 4, Line 35: As a summary of the reference scenarios, this section should include two graphs depicting the 3 reference scenarios. One graph should include the top line of all three radiative forcing scenarios and a second should include the top line CO2 emissions along with a description of the assumed levels of emissions of non-CO2 GHG in the reference case. To the extent either the radiative forcing or the CO2 projections are contingent on modeled emissions of non-CO2 GHGs, this should be indicated as well. (note – the graphs could also be inserted after the bullet points at ES 6, line 32). **Sarah Wade, AJW**

Part A, Chapter ES, Page 4, Line 36: Add a sub-group heading entitled ***Energy System Implications.*** **Sarah Wade, AJW**

Part A, Chapter ES, Page 4, Line 37: Add the paragraph heading ***Global Primary Energy Production*. Sarah Wade, AJW**

Part A, Chapter ES, Page 4, Line 44: Add the appropriate header – something like ***Global Primary Energy Production by Fuel*. Sarah Wade, AJW**

Part A, Chapter ES, Page 5, Line 7: Replace or expand this paragraph so that it includes a specific statement on the ranges of nuclear energy, renewable energy, and efficiency assumptions in the reference case. If replacing with several paragraphs, add appropriate headers, if expanding this paragraph bold the header: ***Non-Fossil Fuel Energy Use*. Sarah Wade, AJW**

Part A, Chapter ES, Page 5, Line 23: Add a paragraph summarizing important transportation assumptions in the reference cases; add appropriate header. **Sarah Wade, AJW**

Part A, Chapter ES, Page 5, Line 23: Add a paragraph with header that refers to the ***High Level of System Improvements In Reference Cases***; include in this paragraph some summary of the points raised throughout the report that a high level of improvements in energy efficiency, transport efficiency, use of nuclear energy, etc are already built into the reference case assumptions. This needs to be highlighted somewhere in the summary. **Sarah Wade, AJW**

Part A, Chapter ES, Page 5, Line 23: Add a sub-group heading that reads: ***Economic Implications*. Sarah Wade, AJW**

Part A, Chapter ES, Page 5, Line 24: Add heading ***Energy Prices*** to the paragraph. **Sarah Wade, AJW**

Part A, Chapter ES, Page 5, Line 31: Add the sub-group heading: ***Emission Trajectories*. Sarah Wade, AJW**

Part A, Chapter ES, Page 5, Line 31: This paragraph should have the heading: ***Fossil Fuel CO2 Emissions*. Sarah Wade, AJW**

Part A, Chapter ES, Page 5, Line 36-46: Combine this into one bullet; add the paragraph heading: ***Non-CO2 GHG Emissions***; keep it under the sub-section of emission trajectories. **Sarah Wade, AJW**

Part A, Chapter ES, Page 6, Lines 2-20: These three paragraphs should be combined into two bullets; the first should have the header: ***Ocean Sinks***; the second should have the header: ***Terrestrial Sinks***; the point about natural biogeochemical removal processes should be made in both bullets. I earlier made the suggestion to replace the reference to stabilizing the human influence with the language from Chapter 1 that referenced stabilizing GHG concentrations because it seems like the non-human impact of sinks is factored into to scenarios. If the important point is that human influence also impacts the

capacity of natural sinks then it may be more appropriate to reference stabilizing human influence but the point should be explained in the context of these paragraphs. **Sarah Wade, AJW**

Part A, Chapter ES, Page 6, Line 34: The section should include two sets of graphs depicting the stabilization scenarios in terms of radiative forcing limits and in terms of emission tonnes. **Sarah Wade, AJW**

Part A, Chapter ES, Page 7, Line 29: Insert sub heading: *Emission Trajectories*. **Sarah Wade, AJW**

Part A, Chapter ES, Page 7, Line 30: Insert the heading: ***Variable Impacts of Sinks*** or something more appropriate. **Sarah Wade, AJW**

Part A, Chapter ES , Page 7, Line 33: Insert Sub-heading: ***Energy System Implications*****. Sarah Wade, AJW**

Part A, Chapter ES , Page 7, Line 34: Insert paragraph heading: **Substantially Different Energy System Needed**; also, it is worth reiterating how difficult it may be just to achieve the aggressive improvements assumed in the reference case. See, for example the statement at Chap 3- page 8- line 20: "The important point here is that these reference scenarios already incorporate substantial technological improvements." **Sarah Wade, AJW**

Part A, Chapter ES, Page 7, Line 40: This paragraph has a typo in the last sentence, it is missing some word(s). The reference to nuclear energy should be separate from the discussion of the implication of not using CCS technologies unless the point was to suggest that CCS and nuclear are the primary tradeoff. Further, this paragraph has several components and should be broken up or expanded to give adequate summary. I would like to see something more quantitative than the term "more heavily" in describing modeled reliance on non-fossil energy sources. Presumably the term "more" refers to the reference case. Therefore, it is worth reiterating the fact that the reference case is built in aggressive reliance on non-fossil energy relative to today's levels. This paragraph should have the heading: ***Non-Fossil Energy Sources***; it should focus only on non-fossil energy sources; it should include more quantitative assessments of the range of nuclear energy, renewable energy and reduced consumption in the stabilization scenarios. The discussion of CCS technology relates to fossil fuel and should be moved to the following paragraph which starts at ES8, Line 4. **Sarah Wade, AJW**

Part A, Chapter ES, Page 8, Line 4: Add reference to CCS from paragraph preceding this (starts on page ES7, line 40). The statement about CCS should include some quantitative range, the paragraphs should have the header: ***Fossil Energy***. **Sarah Wade, AJW**

Part A, Chapter ES, Page 8, Line 9: This paragraph should get the heading: **Non-CO2 Emissions**; it should be moved up under the sub-heading of emissions trajectories that I

suggested be inserted at Part A, Chapter ES, Page 7, Line 29; and the point needs to be better described here in the summary and in the Chapter 4. Chapter 4 presents graphs of emissions of N2O and CH4 but does not talk about the other non-CO2 GHGs in the same fashion. The reader is not able to tell what kind of reductions need to occur in these GHGs and cannot tell what the impact would be if those "substantially reduced" emissions levels are not achieved**. Sarah Wade, AJW**

Part A, Chapter ES, Page 8, Line 12: This paragraph should have the heading: ***Biomass***. **Sarah Wade, AJW**

Part A, Chapter ES, Page 8, Line 20: This is perhaps the most important message from the entire scenarios effort yet it is buried here and is written in such a way that it is difficult to comprehend how important it is. I'm sorry that I don't have a suggestion for language that I think would be appropriate and accurate – l defer to the authors. I would like to see some indication of the tradeoffs between high and low radiative forcing limits not only in relation to magnitude and timing of changes in the energy system but also in the potential for inducing climate change impacts related to warming. I realize this is out of the scope of the report, but as written, it seems like the "easy" solution is to simply select a higher radiative forcing limit in order to avoid or delay substantial changes in the energy system -- there is no indication of the potential consequences of such a selection. Chapter 5, page 12 line 4 presents potentially suitable language that could be referenced here. I would also like to see language that is more quantitative if possible.
Sarah Wade, AJW

Part A, Chapter ES, Page 8, Line 24: This paragraph should be moved up to the emissions trajectories sub section that I suggested be inserted at line ES7 line 29; it should have the heading: ***Scale and Timing of Reductions***; it should include a summary of the range of reductions in tons from the scenarios – at least for CO2.
Sarah Wade, AJW

Part A, Chapter ES, Page 8, Line 30: This paragraph should be moved up to the emissions trajectories sub-section I suggested be inserted at line ES7 line 29; it should have the heading: ***Long Term CO2 Emissions Fall Toward Zero*****. Sarah Wade, AJW**

Part A, Chapter ES, Page8, Line 45: Because this statement is so broad, it is not clear how the statement in this paragraph differs from the statement in the paragraph at ES7 line 40. If appropriate, I suggest combining them and including them under the sub-heading of Energy System Implications – if instead there is an important and distinct point, it should be made more clearly. **Sarah Wade, AJW**

Part A, Chapter ES, Page 9, Line 5: Because this statement is so broad, it is not clear how this paragraph differs from the paragraph at ES8 Line 4. If there is a distinct point that is not made in the earlier paragraph, it should be clarified here. **Sarah Wade, AJW**

Part A, Chapter ES, Page 9, Lines 11- ES10, Line 16: These bullets would clearly fall under the subgroup of Economic Implications of the Stabilization Scenarios Findings section and should be placed in this section and given appropriate headers.
Sarah Wade, AJW

Part A, Chapter ES, Page 9, Line 35: The discussion of non-CO2 GHGs here relates to their ultimate potential impact on the cost of meeting the various radiative forcing limitations based on their impact on the necessary stringency of changes to CO2 in the energy system. It would be more clear if the rationale were described in a less convoluted manner and if some qualitative statement about the range of impact could be made. The implication seems to be that if the Non-CO2 GHG limits are not achieved then there would be a need for additional (and presumably more costly) CO2 reductions. Regarding the discussion of radiative forcing throughout the report, it seems like the Levels 1-4 radiative forcing limits in the scenarios only compare to the approximate range of 450-750 ppm CO2 if the modeled reductions of non-CO2 GHGs are achieved. If not, then do the radiative forcing limits compare to higher levels of CO2 concentrations?
Sarah Wade, AJW

Part A, Chapter ES, Page 12, Line 20: Chapter 5 (page 1, lines 41-45) identifies potential users and uses of scenarios as follows: "The possible users of emissions scenarios are many and diverse and include climate modelers and the science community, those involved in national public policy formulation, managers of Federal research programs, state and local government officials who face decisions that might be affected by climate change and mitigation measures, and individual firms, farms, and members of the public." But, Chapter 5 goes on to describe that such users would require different scenarios than called for in the Prospectus and as a result, it seems, provided in the report. Further, throughout the report there are caveats suggesting that the report provides the "barest glimpse of the uncertainty (ES-12-25) or that it is only the first step in a process of developing information. With these statements, the report sends mixed messages about who could use the insights from the report and to what purpose. Today, there are several pieces of legislation being debated in the US Congress, millions (if not billions) are being spent on climate technology development, and several states and other nations are implementing climate policy. The information in this report may be supplanted by other scenario analyses in the works today and it may need to be vetted against sensitivity and uncertainty analyses, but it also represents the best of what we know and think now. I would rather policy makers use it than rely only on older, less sophisticated thinking. Yet it is difficult to get a clear sense of how the information in this report could be considered by people involved in those activities today. It would be helpful if the authors could more clearly articulate guidance for using the information in this report as it stands today.
Sarah Wade, AJW

2. Concept of Radiative Forcing Requires Better Explanation and Comparison

I am an "interested non-specialist" who is better informed on climate science than the average person, yet I am struggling to fully grasp the concept of radiative forcing and to compare it to atmospheric concentrations – especially of CO2e. Ultimately it is going to be important to relate

these scenarios to emissions. For this work to be useful in the public and private discussions of decisionmakers, the report should contain a plain English explanation of why radiative forcing is the primary metric used in the report as well as something of a primer to help interested non-specialists to navigate this approach. Chapter 1 attempts to do this but falls short of fully explaining the comparison.

The radiative forcing limits are presented in relation to their approximate CO2 concentrations. However, since the non-CO2 GHGs make up 20-30% of the radiative forcing in the reference scenarios, it is hard to figure out what that means regarding the approximate CO2 concentration – is Level 1 approximately 450 ppm or is it approximately 450 ppm CO2 plus some concentration of non-CO2 GHGs? And, if so, is the potential impact on climate equivalent to 450 CO2, 450 CO2e or a number greater than 450 ppm CO2 or CO2e? It would be helpful to find an easy-to-understand explanation of the difference and the implications for potential climate effects.

> **Part A, Chapter ES, Page 3, Line 39**: Radiative forcing needs to be explained and compared to CO2 or CO2e concentrations in a clear manner. Such an explanation could be inserted at this point or referenced as an Appendix. **Sarah Wade, AJW**
>
> **Part A, Chapter 1, Page 3, Line 1**: The description of radiative forcing reads: "the Prospectus also directed that stabilization levels be chosen to provide results easily compared with those from previous scenario exercises based only on CO2 concentrations. Radiative forcing levels were constructed so that the resulting CO2 concentrations, after accounting for radiative forcing from the non-CO2 GHGs, would be roughly 450 ppmv, 550 ppmv, 650 ppmv, and 750 ppmv. Based on this requirement, the four stabilization levels were chosen as 3.4 W/m2 (Level 1), 4.7 W/m2 (Level 2), 5.8 W/m2 (Level 3), and 6.7 W/m2 (Level 4)." It may not be a material concern, but this does not add up to me – or, rather, it is not an easy comparison to make. For example, in Figure 4-2 the IGSM Level 1 limit of 3.4 W/m2 is actually roughly 450 PPM CO2 plus between roughly 0.75 - 1 W/m2 of effect from the non-CO2 GHGs. In this case it appears that a radiative forcing limit of about 2.5 W/m2 is more closely aligned with the CO2 concentration of 450 PPM. Is this correct?
>
> To focus on the higher level of 3.4 W/m2 means that a certain level of non-CO2 GHG must be achieved. Two things are not clear: 1) if the modeled levels of non-CO2 GHGs are not achieved would the limit of 3.4 W/m2 actually be more like a higher concentration of CO2 (in other words, how dependent on the non-CO2 GHGs reductions is the comparison)? And, (2) how does the effect of the proposed Level 1 limit of 3.4 W/m2 compare to what is believed to be the climate impacts of 450 PPM CO2 or 450 PPM CO2e?
>
> The models include "substantial" reductions in the non-CO2 GHGs, are these similar to what is already considered in studies that assess climate impacts of 450 PPM CO2 or 450 PPM CO2e? in other words, is this not a material difference than what is already discussed as the basis of CO2 PPM scenarios? Also, at least the MiniCAM model, prices

non-CO2 GHGs are based on conversion to C using global warming potentials – this brings to mind CO2e.

These questions need to be addressed, given that non-CO2 GHGs appear to represent about 20-30% of the radiative forcing in both the reference case and the scenarios – this is too big a piece of the scenarios to leave questions of comparison unexplained. And, if this report is attempting to highlight the important role of non-CO2 GHGs in containing the cost of CO2 reductions, that concept should be more clearly indicated.
Sarah Wade, AJW

3. Link Radiative Forcing to Tonnes More Clearly

It should be easier for the reader to translate the findings into tonnes and to relate the findings to both global and US systems.

Part A, Chapter 3, Page 17, Line 17: The text of the report refers to: "Figure 3.15 Global and U.S. Emissions of CO2 from Fossil Fuels and Industrial Sources across Reference Scenarios." Yet on page 3-37 Figure 3-15 shows only the global emissions. A new graph showing the US emissions from the reference cases should be included here. **Sarah Wade, AJW**

Part A, Chapter 3, Page 19, Line 7: Figure 3-18 should be modified to include the modeled US reference case for these gases. **Sarah Wade, AJW**

Part A, Chapter 3, Page 19, Line 38: Figure 3-19 should be modified to include the modeled US reference case for these gases. **Sarah Wade, AJW**

Part A, Chapter 4, Page 8, Line 41: A new figure should be added to complement Figure 4-6 but to present the findings for the US (Fossil Fuel and CO2 Emissions Across Scenarios for the US). **Sarah Wade, AJW**

Part A, Chapter 4, Page 10, Line 16: New figures should be added here that present the stabilization scenarios for the long-lived and short-lived F gasses, these figures should mirror the information presented as the reference case for each in Figure 3-19. New figures should also be added to this section to complement Figures 4-7 and 4-8 and the new figures for the F gases to present the findings for the US. **Sarah Wade, AJW**

4. Remind Readers of Important Caveats throughout the Report

First, is it the case that the results in these scenarios would tend to understate the cost and degree of difficulty in achieving the stabilization targets? It seems that this tendency would be driven by at least three features of all the scenarios:

a. There are aggressive technology assumptions in the reference case
b. It is assumed the whole world participates in reductions
c. There appears to be a relatively frictionless market

If true, this point should be emphasized throughout the report. If not true, it would be helpful to explain why this is not the case.

In addition, there are a few instances where it would be useful to ground the report's findings in the larger context of being just one piece of information necessary to assess climate change policy. Experts will most likely keep in their minds a set of caveats regarding the interpretation of results in this report. The average reader may forget to do so and thus the burden is on the authors to continue to remind the reader of these caveats. In particular:

> **Part A, Chapter 4, Page 3, Line 31**: The sentence reads: "There is a strong economic argument that mitigation costs will be lower if abatement efforts start slowly and then progressively ramp up, particularly for CO2." The following paragraph adds the caveat that: "What constitutes such a cost-effective "slow start" depends on the concentration target and the ability of economies to make strong reductions later." The caveat needs to be emphasized more strongly and linked more closely with the first statement. It seems that the report is trying to make the point that no matter what target is selected, it will generally be more cost-effective to progressively ramp up abatement than to attempt more rapid wholesale change, provided the economy has the ability to increase reductions in the future. As written, I fear people will miss the caveat and only focus on the economic argument for a "slow start" – it does not seem like this is the sole point of the section and so should be clarified. **Sarah Wade, AJW**
>
> **Part A, Chapter 4, Page 23, Line 33**: This paragraph starts with the question: "Estimating the macroeconomic cost of stabilization is not a simple task either conceptually or computationally. From an economic perspective, cost is the value of the loss in welfare associated with undertaking the required policy measures – or equivalently, the value of activities that society will not be able to undertake as a consequence of pursuing stabilization?" This seems to be an incomplete question at this point in the report. A more complete question would remind the reader that there are consequences from not pursuing stabilization (i.e., the benefits) that are not valued in the scenario work and which I think are important in considering the macroeconomic cost of stabilization. If they are not important in considering macroeconomic cost of stabilization, the rationale should be explained to reader at this point in the report. **Sarah Wade, AJW**
>
> **Part A, Chapter 5, Page 3, Line 22**: This section should include a reminder that all three reference scenarios include aggressive assumptions about renewable energy, efficiency and nuclear energy. **Sarah Wade, AJW**

5. Discuss Technology Changes More Completely

> **Part A, Chapter 4, Page 12, Line 20 (**Section 4.4.2**)** This section presents an interesting discussion of the potential role of CCS technology. I would like to see the same assessment of the role of nuclear and renewable energy included here. This assessment should also be included for the US – even if the US numbers represent simply one potential pathway. **Sarah Wade, AJW**

Part A, Chapter 4, Page 13, Line 29: Table 4-5 should include modeled Cumulative CCS in 2030 as well. (assuming virtually no CCS in 2000 and a linear progression in the increase of CC per year between then and 2030, would the cumulative modeled CCS numbers range from 9-40 GTCO2 in 2030 for Level 1? If so, this is a lot easier to conceptualize the implications than it is by considering 17-42 PgC by 2050.) The report should present the same type of information as is presented tables 4-4 and 4-5 for the other main energy sources (nuclear, renewable energy, biomass and efficiency) in separate tables for each energy type. This information should also be presented for all energy sources and CCS as a modeled US number as well. Even though these are caveated model results and not predictions of the future, these are the kind of concrete numbers that people today can relate to in order to get a better appreciation for the scale of change being discussed. It would be preferable to provide similar tables for the US based on the modeled pathways. It seems like this information could based on Figures 4-13 and 4-14. **Sarah Wade, AJW**

6. Miscellaneous

Part A, Chapter 4, Page 14, Line 36: It is unclear whether the figures presenting US energy statistics (Figure 4-13, 4-14, 4-15 – and Figure 3-8) are based on US energy consumption or production. It appears they are based on consumption which is represented in Chapter 3 as being greater in the US than production because of imports. Therefore, the implications for US emissions from energy are not entirely clear.
Sarah Wade, AJW

Part A, Chapter 4, Page 22, Line 6: Table 4.7 includes a note at the bottom that "the added cost should not change because $100 remains $100." If this is true, then the percentages would change dramatically at least for some of the fuels. I would urge that percentages be recalculated based on more current energy prices.
Sarah Wade, AJW